6 What Are the Indications for Intubation in the Critically Ill Patient?

Meredith Collard, Meghan Lane-Fall

The specific indications for endotracheal intubation are difficult to define, in part because large-scale studies examining the question are lacking and in part because clinical practice is evolving. Although a seasoned practitioner is usually able to identify a patient who requires intubation, it is challenging to explain the precise parameters used to arrive at this decision. In addition, advancements in oxygen delivery systems and noninvasive forms of ventilation have changed the decision-making process in recent years. In this chapter, we describe strategies for diagnosing respiratory failure and deciding whether endotracheal intubation is needed for support. We also briefly discuss reasons to avoid endotracheal intubation.

We divide indications for intubation into two broad categories: patients with physiologic compromise currently in need of support ("actual need") and those at high risk of decompensation ("impending need"). Actual need for intubation occurs when the patient is physiologically unstable as a result of impaired gas exchange (e.g., hypoxic respiratory failure or hypercarbic ventilatory failure). Impending need is present when respiratory compromise can be reasonably anticipated (e.g., impaired consciousness, airway edema). These two general indications are based on accepted practice, with few or no data available to support specific guidelines. This poor evidence base is reflected in Marino's statement that "…the indication for intubation and mechanical ventilation is thinking of it."[1]

As with any invasive procedure, informed consent for endotracheal intubation should be obtained from the patient or proxy if possible. Advanced directives should be consulted to ensure that intubation is consistent with the patient's goals of care, and patients and families should be counseled about the expected duration of mechanical ventilation. Previous intubation records should be reviewed when possible to determine whether difficulty in securing the patient's airway is likely to occur.

ACTUAL NEED FOR INTUBATION

Signs and Symptoms

Acute hypoxic respiratory failure results from inadequate exchange of oxygen across the pulmonary alveolar-capillary membrane. This impairment leads to a decrease in arterial oxygen tension (hypoxemia) and insufficient delivery of oxygen to tissues and cells (hypoxia). In addition, because oxygen delivery is the product of arterial oxygen content and cardiac output, hypoxia can also occur secondary to decreased cardiac output, anemia, or abnormal oxygen-hemoglobin binding affinity. In the medical literature, hypoxic respiratory failure is often described as type I failure when hypoxemia is present without hypercarbia. When associated with hypercarbia, this is described as type II respiratory failure.

In contrast, acute ventilatory failure (and subsequent hypercarbia and respiratory acidosis) results from inadequate removal of gas from distal alveoli. Mild ventilatory failure can exist alone or, when impairment is more severe, may be associated with hypoxemia. Ventilatory failure can result from a primary lung process such as chronic obstructive pulmonary disease, or it can occur secondary to disorders in the cardiac, neurologic, metabolic, or other systems.

Both the symptoms and signs of hypoxia and hypercarbia are nonspecific and are noted in Table 6-1. In addition, the signs and symptoms of hypercarbia also depend on the patient's baseline $Paco_2$ (partial pressure of carbon dioxide in arterial blood) the absolute value of $Paco_2$, and the rate of change. Unlike hypoxemia, chronic hypercarbia may be well tolerated. Eliciting a history of chronic CO_2 retention and performing careful serial evaluations of arterial pH are essential because hypercarbia with a near-normal pH is a sign of chronic compensation and often does not reflect an acute disorder. Symptoms of acute hypercarbia may include respiratory fatigue and suggest that the patient soon may be unable to achieve the minute ventilation required to maintain a normal pH.

Many disease processes can lead to type I failure (Table 6-2) or type II failure (Table 6-3). These processes can be divided into pulmonary and nonpulmonary processes. Although they are presented separately, there is some overlap in these two types of respiratory failure. For the purposes of this chapter, respiratory and cardiac arrest are included as ventilatory (type II) failure.

Table 6-1 Symptoms and Signs of Hypoxia and Hypercarbia

Hypoxia	Hypercarbia
Symptoms	***Symptoms***
Confusion	Confusion
Dyspnea*	Dyspnea
Exhaustion	Exhaustion
Headache	Headache
Irritability	
Signs	***Signs***
Agitation	
Central cyanosis	Accessory respiratory muscle use
Coma	Cardiovascular collapse
Increased work of breathing	Coma
Lethargy	Flapping tremor
Seizures	Increased work of breathing
Somnolence	Lethargy
Tachypnea*	Seizures
	Shallow or small tidal volume breathing
	Somnolence
	Tachypnea

*May or may not be present depending on the cause of the hypoxia.

Table 6-2 Causes of Hypoxemic Respiratory Failure*

PULMONARY DISORDERS
Intrinsic lung disease
Lung consolidation (e.g., tumor)
Pathophysiologic state
Acute respiratory distress syndrome (ARDS)
Atelectasis
Lung consolidation (e.g., hemorrhage)
Noncardiogenic pulmonary edema
Pneumonia
Transfusion-related acute lung injury (TRALI)
NONPULMONARY DISORDERS
Cardiac disorders
Cardiogenic pulmonary edema
Vascular disorders
Pulmonary embolism
Toxins
Carbon monoxide

*These are causes of type I respiratory failure (hypoxia without hypercarbia).

Table 6-3 Causes of Hypercarbic Ventilatory Failure

PULMONARY DISORDERS
Intrinsic lung diseases
Asthma
Chronic obstructive pulmonary disease
Pathophysiologic state
Airway obstruction (functional or mechanical)
Obstructive sleep apnea
NONPULMONARY DISORDERS
Neurologic disorders
Brainstem or medullary stroke
Central sleep apnea
Critical illness myopathy or polyneuropathy
Myasthenia gravis, Guillain-Barré syndrome
Obesity-hypoventilation syndrome
Opiate or sedative overdose
Phrenic nerve dysfunction
Cardiac disorders
Cardiac arrest
Cardiogenic shock
Heart failure
Vascular disorders
Pulmonary embolism
Metabolic disorders
Hypomagnesemia
Hypophosphatemia

Diagnosis of Respiratory Failure

Hypoxemia is usually defined as a Pao_2 (partial pressure of oxygen in arterial blood) of less than 60 mm Hg (8 kPa). The gold standard test for diagnosing hypoxemia is arterial blood gas testing. However, pulse oximetry, being continuous and inexpensive, is more commonly used for detection of decreased oxygen levels. However, it is important to note that pulse oximetry measures the saturation of hemoglobin, not Pao_2 (a reflection of oxygen dissolved in the blood) or oxygen content (a reflection of both bound and unbound O_2). Thus, pulse oximetry may be unreliable in cases in which the patient may have a normal Pao_2 but a low available O_2 content, such as in severe anemia, carbon monoxide poisoning, methemoglobinemia, or peripheral vasoconstriction.

Normal Pao_2 levels are 80 to 100 mm Hg in a healthy patient breathing room air and can exceed 500 mm Hg in a patient breathing 100% oxygen. Pulse oximetry values may remain normal until Pao_2 decreases from normal values to less than 60 mm Hg. For this reason, the alveolar-arterial oxygen gradient should be evaluated in patients receiving a high Fio_2 (fraction of inspired oxygen) because a widening alveolar-arterial oxygen gradient is a sign of worsening hypoxemia. Therefore, the decision to intubate must take into consideration that low pulse oximetry values coincide with significant hypoxemia, but normal oxygen saturation does not exclude hypoxemia, especially in patients receiving a high Fio_2.

Hypercarbia, commonly defined as a $Paco_2$ of more than 45 mm Hg (6 kPa), should also be diagnosed with

arterial blood gas sampling. Noninvasive diagnosis of hypercarbia is problematic. End-tidal CO_2 monitoring is used in operating rooms, but accurate reflection of $Paco_2$ requires a sealed airway and consistent tidal volumes: gas leakage, dead space ventilation, and low cardiac output may provide misleading data. Pulse oximetry should not be used to gauge the adequacy of ventilation because normal oxygen saturation can be found in the presence of significant hypoventilation, providing false confidence.

With both hypoxia and hypercarbia, it is important to follow Pao_2 and $Paco_2$ changes over time, which may provide more information than absolute values.

In addition to instruments and tests being used to detect worsening ventilatory failure, it is essential to evaluate the patient's clinical condition for signs of fatigue and impending respiratory collapse on a continuous basis. Clinical assessment, combined with medical experience, is the most important tool for identifying patients requiring early intubation. Signs of impending collapse often include worsening dyspnea, tachypnea, use of accessory breathing muscles, and rapid shallow breathing. Planned endotracheal intubation in a controlled setting is always preferable to emergent airway management.

Treatment of Acute Respiratory Failure

The initial treatment of all actual or impending cases of respiratory failure is the same: ensure a patent airway, adequate ventilation, and adequate fraction of inspired oxygen. Little research has been performed on minimal safe Pao_2 levels in critically ill patients. Pao_2 values of 50 to 60 mm Hg (6.5 to 8 kPa) or arterial oxygen saturation of 88% to 90% are often anecdotally suggested as minimum acceptable values during treatment of hypoxemia. However, for patients in shock states, with acute myocardial ischemia or after brain injury, higher arterial oxygen content levels would appear advantageous. Except in patients with right to left shunt greater than 30%, hypoxemia will improve with delivery of high Fio_2.

Not all patients with respiratory compromise require intubation and mechanical ventilation. Initial treatment of hypoxemia often starts with low-flow nasal cannula and escalates to 100% with a nonrebreather mask or high-flow O_2 therapy. Indeed, high-flow oxygen therapy shows promise in avoiding noninvasive ventilation in patients with mild to moderate respiratory failure.[2] If hypoxemia fails to reverse with supplemental oxygen and the patient is symptomatic, noninvasive assisted ventilation may be attempted.[3] If a patient is still unable to maintain minimal oxygen saturation while breathing 100% Fio_2, endotracheal intubation and mechanical ventilation will be required to improve oxygenation. During the process of intubation, high oxygen tensions should be maintained when possible. High-flow oxygen may be superior to nonrebreather face masks for maintaining oxygen saturation during the process of intubation.[4]

In cases of hypoxemia persisting despite intubation, mechanical ventilation with progressive levels of positive end expiratory pressure, and administration of high inspired oxygen tensions, additional therapeutic modalities such as continuous neuromuscular blockade, prone positioning, inhaled nitric oxide or nebulized prostacyclin, or extracorporeal membrane oxygenation should be considered.

It is crucial to diagnose the underlying cause of type I or type II failure so that adequate therapy such as antibiotic administration or surgical source control can be instituted. However, with type II failure, immediate management may also be affected by the etiology of the derangement. Cases in which ventilatory failure is not the primary disorder may require ventilatory support, but promptly administered definitive therapy can rapidly reverse respiratory compromise. For example, opioid or benzodiazepine overdose can be treated with reversal agents, and ventilatory failure secondary to cardiogenic shock can improve with inotropic agents and diuretics.

When specific medical therapies are not applicable or not successful in increasing ventilation, or when ventilatory failure is the primary problem, treatment is focused on providing a means to increase minute ventilation. Most often, this support is provided with either noninvasive positive-pressure ventilation or endotracheal intubation and mechanical ventilation. Therapy is often initiated when hypercarbia is associated with worsening hypoxemia or when the patient experiences cardiac or neurologic failure secondary to effects of elevated CO_2. The assisted ventilation provided from noninvasive positive-pressure therapy (i.e., steroids, bronchodilators, diuretics, nitrates) can provide additional time for treatment of underlying medical conditions. Using this approach to manage exacerbations of chronic obstructive pulmonary disease[5,6] and congestive heart failure[7,8] (both level of evidence A) is well supported by evidence showing improved morbidity and mortality for patients managed noninvasively.

When optimal medical management and/or noninvasive ventilation fail, or when there is a contraindication to the use of noninvasive ventilation (e.g., obtundation, recent esophageal anastomosis), endotracheal intubation and mechanical ventilation are indicated.

Impending Needs for Intubation

In the absence of frank respiratory failure, endotracheal intubation may still be appropriate if respiratory failure can be reasonably anticipated (Table 6-4). For example, patients with traumatic injury or swelling of the face, neck, or airway are at risk for airway obstruction. Patients with significant aspiration of particulate matter may be candidates for brief endotracheal intubation to facilitate bronchoscopy and lavage. In cases of metabolic acidosis, the respiratory drive to correct acidemia may lead to increased work of breathing and respiratory failure. When the underlying metabolic process, such as neuroleptic malignant syndrome or septic shock, cannot be reversed quickly, intubation and mechanical ventilation may be needed to increase pH.

Impaired consciousness with inability to protect the airway is another often-described indication for endotracheal intubation. Neurologic indications for endotracheal intubation are important because intubation for impaired consciousness and presumed airway protection may account for 20% of patients intubated in the intensive care unit (ICU).[9] The trauma and neurologic literature often cites a Glasgow Coma Scale (GCS) value of 8 or less as a

Table 6-4 Potential Indications for Endotracheal Intubation in the Absence of Respiratory Failure

AIRWAY OBSTRUCTION (ACTUAL OR IMPENDING)
Angioedema
Foreign body
Hemorrhage
Metabolic acidosis
Secretions
Trauma
LOSS OF PROTECTIVE REFLEXES (ACTUAL OR IMPENDING)
Coma
Pharmacologic sedation
Seizure
IMPENDING RESPIRATORY FAILURE (TYPE I OR TYPE II)
Asthma exacerbation
Metabolic acidosis

specific indicator for endotracheal intubation.[10] The GCS criterion for intubation is not based on concerns for respiratory distress but rather on the concern for development of worsening consciousness, hypoventilation, and airway protection. This arises from a retrospective analysis of the National Traumatic Coma Data Bank that demonstrates a greater risk for aspiration and worse clinical outcome in comatose patients (GCS <8) not endotracheally intubated.[11] Subsequent studies support this conclusion.[12] Severe brain injury is associated with decreased respiratory drive and hypoventilation, and patients likewise often have decreased muscle tone. This may increase the risk for airway obstruction and a failure to clear secretions.[13] In addition, patients with traumatic brain injury and subarachnoid hemorrhage have been shown to be at increased risk for having pulmonary edema. Indeed, as many as 30% of these patients may progress to severe acute lung injury or acute respiratory distress syndrome.[14]

Although intubation for a depressed level of consciousness is regarded as a standard of care, no definitive controlled studies are available on the subject. Recent studies dispute the requirement for intubation based on neurologic status alone. Coplin et al.[15] studied criteria used for extubation and found that neither level of consciousness nor the presence of a gag or cough reflex predicted success. In this study, 80% of patients with a GCS value of 8 or less and 90% of patients with a GCS value of 4 or less were successfully extubated. This also was the case for 88% of patients with an absent or weak gag reflex and 82% of patients with an absent or weak cough. In addition, studies have shown that the risk for ventilator-induced lung injury is increased in patients with traumatic brain injury and subarachnoid hemorrhage, and many of these patients have ventilator-associated pneumonia. This may lead to a prolonged hospital stay and increased mortality.[16,17]

Impaired consciousness requiring intubation may also occur when respiratory depression occurs secondary to sedation required to facilitate patient care. For instance, traumatically injured patients may require deep sedation and intubation to perform necessary tests and procedures. In addition, patients with status epilepticus may require deep sedation for treatment of seizures, and patients receiving high doses of benzodiazepines for treatment of alcohol withdrawal may become obtunded with therapy.

Therapeutic hyperventilation is no longer recommended for patients with traumatic brain injury because of the elevated risk of cerebral ischemia.[18-20] However, brief, target-directed hyperventilation still may be indicated in cases of acute neurologic deterioration secondary to herniation or sudden intracranial pressure elevation.[20]

WHY MIGHT ENDOTRACHEAL INTUBATION BE UNDESIRABLE?

Endotracheal intubation and mechanical ventilation are not benign procedures. The process of intubation usually requires deep sedation and usually temporary neuromuscular blockade. Sedation in an already compromised patient can lead to further deterioration, including cardiac arrest. Difficulty securing the airway may lead to hypoxemia with subsequent neurologic and cardiac sequelae. Finally, damage to anatomic structures may occur, and these mechanical complications may require additional intervention.[21]

Subsequently, even if the initial intubation is tolerated, continued sedation and mechanical ventilation may cause ICU delirium, which is associated with short- and long-term morbidity.[22]

CONCLUSION

The goal of endotracheal intubation and mechanical ventilation is to provide the delivery of the oxygen and ventilation that is primary to a patient's survival. The decision to proceed with this invasive procedure requires an understanding of the pathologic and physiologic disorders that necessitate its use. Although much information is available on the study of respiratory pathology and physiology and on the delivery and modes of mechanical ventilation, little has been written about the specific indicators for endotracheal intubation. Because of the severity of a patient's clinical condition and difficulty with study design, strong evidence and randomized controlled studies are not available on the subject. Until better clinical trials are available, one must use available clinical information in combination with specific medical knowledge and experience in making this decision.

AUTHORS' RECOMMENDATIONS

- Indications for endotracheal intubation and mechanical ventilation are commonly divided into hypoxic respiratory failure, hypercarbic ventilatory failure, and impaired consciousness requiring airway protection.
- Indications are all based on accepted practice, with few or no data available to support specific guidelines.
- Clinical assessment, combined with medical experience, is the most important tool for identifying patients requiring intubation.
- Arterial blood gas and $Paco_2$ measurements are necessary to evaluate hypercarbic ventilatory failure because pulse oximetry values can remain near normal until ventilatory collapse.

ACKNOWLEDGMENTS

The authors acknowledge the contributions of Drs. Jason Brainard and Clifford Deutschman, who authored a previous edition of this chapter.

REFERENCES

1. Marino P. Principles of mechanical ventilation. In: Marino P, ed. *The ICU Book*. Philadelphia: Lippincott, Williams & Wilkins; 2007.
2. Parke RL, McGuinness SP, Eccleston ML. A preliminary randomized controlled trial to assess effectiveness of nasal high-flow oxygen in intensive care patients. *Respir Care*. 2011;56(3):265–270.
3. Thille AW, Contou D, Fragnoli C, Córdoba-Izquierdo A, Boissier F, Brun-Buisson C. Non-invasive ventilation for acute hypoxemic respiratory failure: Intubation rate and risk factors. *Crit Care*. 2013;17(6).
4. Miguel-Montanes R, Hajage D, Messika J, et al. Use of high-flow nasal cannula oxygen therapy to prevent desaturation during tracheal intubation of intensive care patients with mild-to-moderate hypoxemia. *Crit Care Med*. 2015;43(3):574–583.
5. Keenan SP, Sinuff T, Cook DJ, Hill NS. Which patients with acute exacerbation of chronic obstructive pulmonary disease benefit from noninvasive positive-pressure ventilation? A systematic review of the literature. *Ann Intern Med*. 2003;138(11):861–870. +I827.
6. Ram FS, Picot J, Lightowler J, Wedzicha JA. Non-invasive positive pressure ventilation for treatment of respiratory failure due to exacerbations of chronic obstructive pulmonary disease. *Cochrane Database Syst Rev*. 2004;3:Cd004104.
7. Masip J, Roque M, Sánchez B, Fernández R, Subirana M, Expósito JA. Noninvasive ventilation in acute cardiogenic pulmonary edema: systematic review and meta-analysis. *J Am Med Assoc*. 2005;294(24):3124–3130.
8. Peter JV, Moran JL, Phillips-Hughes J, Graham P, Bersten AD. Effect of non-invasive positive pressure ventilation (NIPPV) on mortality in patients with acute cardiogenic pulmonary oedema: a meta-analysis. *Lancet*. 2006;367(9517):1155–1163.
9. Esteban A, Anzueto A, Alía I, et al. How is mechanical ventilation employed in the intensive care unit? An international utilization review. *Am J Respir Crit Care Med*. 2000;161(5):1450–1458.
10. Marik PE, Varon J, Trask T. Management of head trauma. *Chest*. 2002;122(2):699–711.
11. Marshall LF, Becker DP, Bowers SA, et al. The National Traumatic Coma Data Bank. Part 1: design, purpose, goals, and results. *J Neurosurg*. 1983;59(2):276–284.
12. Winchell RJ, Hoyt DB. Endotracheal intubation in the field improves survival in patients with severe head injury. *Arch Surg*. 1997;132(6):592–597.
13. Johnson VE, Huang JH, Pilcher WH. Special cases: mechanical ventilation of neurosurgical patients. *Crit Care Clin*. 2007;23(2):275–290.
14. Kahn JM, Caldwell EC, Deem S, Newell DW, Heckbert SR, Rubenfeld GD. Acute lung injury in patients with subarachnoid hemorrhage: incidence, risk factors, and outcome. *Crit Care Med*. 2006;34(1):196–202.
15. Coplin WM, Pierson DJ, Cooley KD, Newell DW, Rubenfeld GD. Implications of extubation delay in brain-injured patients meeting standard weaning criteria. *Am J Respir Crit Care Med*. 2000;161(5):1530–1536.
16. Friedman JA, Pichelmann MA, Piepgras DG, et al. Pulmonary complications of aneurysmal subarachnoid hemorrhage. *Neurosurg*. 2003;52(5):1025–1032.
17. Zygun DA, Zuege DJ, Boiteau PJE, et al. Ventilator-associated pneumonia in severe traumatic brain injury. *Neurocrit Care*. 2006;5(2):108–114.
18. Stocchetti N, Maas AI, Chieregato A, van der Plas AA. Hyperventilation in head injury: a review. *Chest*. 2005;127(5):1812–1827.
19. Muizelaar JP, Marmarou A, Ward JD, et al. Adverse effects of prolonged hyperventilation in patients with severe head injury: a randomized clinical trial. *J Neurosurg*. 1991;75(5):731–739.
20. Bratton S, Chestnut R, Ghajar J, et al. Guidelines for the management of severe traumatic brain injury. XIV. Hyperventilation. *J Neurotrauma*. 2007;24(suppl 1):S87–S90.
21. Pacheco-Lopez PC, Berkow LC, Hillel AT, Akst LM. Complications of airway management. *52nd Conference on Adult Artificial Airways and Airway Adjuncts*. 2014;59(6):1006–1021.
22. Peitz GJ, Balas MC, Olsen KM, Pun BT. Wesley Ely E. Top 10 myths regarding sedation and delirium in the ICU. *Crit Care Med*. 2013;41(9 suppl. 1):S46–S56.